Competency 2.3 **Radiation protection personnel shall demonstrate a familiarity level knowledge of the content of the following industry standards for radiation generating devices and the application of the following standards to Department of Energy radiation protection practices:**

- **ANSI N 43.2-1988, *Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment***
- **ANSI N 543-1974, *General Safety Standard for Installations Using Non-Medical X-Ray and Sealed Gamma Ray Sources Energies Up to 10 MeV***
- **10 CFR 34, *Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations***
- **10 CFR 34.31, Training**

1. Supporting Knowledge and/or Skills

a. Describe the content of the listed industry standards and, in general terms, discuss their significance to Department radiation protection practices.

b. Compare the requirements of the documents listed above to the contents of the DOE *Radiological Control Manual*.

2. Summary

DOE/EH-0256T (Revision 1), *Radiological Control Manual*, directs that all Site-Specific Radiation Control Manuals contain provisions for the types of radiation-generating devices (RGDs) found at those sites. The *Radiological Control Manual* further directs that DOE Order 5480.4, *Environmental Protection, Safety and Health Protection Standards*, be used for meeting the intent of the Manual. DOE Order 5480.4, in turn mandates the use of ANSI N 543-1974, *General Safety Standard for Installations Using Non-Medical X-Ray and Sealed Gamma Ray Sources Energies Up to 10 MeV*; ANSI N 43.2-1988, *Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment*; and 10 CFR 34, *Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations* for meeting its requirements covering RGDs.

NOTE: ANSI N 543-1974 has been superseded by ANSI N 43.3-1993, *General Safety Standard for Installations Using Non-Medical X-Ray and Sealed Gamma Ray Sources Energies Up to 10 MeV*

RGDs are not precisely defined in the *Radiological Control Manual*; however, Implementation Guide (IG), G-10 CFR 835/C3 (Revision 1), *Radiation-Generating Devices*, defines RGDs as "a collective term for devices which produce ionizing radiation, sealed sources with emit ionizing radiation, small particle accelerators used for single purpose application that produce ionizing radiation (e.g., radiography), and electron-generating devices that produce x-rays incidentally."

ANSI N 43.2-1988, *Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment*, applies to x-ray diffraction and fluorescence analysis equipment, and fluorescence analysis equipment using radioactive material. These devices are also known as analytical equipment. This standard reviews the types of injuries resulting from accidental exposure to ionizing radiation from these devices, establishes design criteria, sets up requirements for operating procedures, and recommends personnel monitoring programs.

X-ray diffraction units and x-ray fluorescence analysis equipment both generate high-intensity ionizing radiation that can cause severe and permanent injury to any part of the body that is exposed to the primary beam. Most of the accidental overexposures from industrial x-ray sources have involved analytical equipment. Fingers and eyes are the most common body parts exposed during accidents, and exposures have resulted in amputations and cataracts.

ANSI N 43.2 recognizes two classes of x-ray systems, enclosed-beam systems and open beam systems. Both types are required to have a beam trap, visible signal of x-ray production at the exposure switch as well as at the source housing, and a fail-safe interlock for x-ray tube disassembly. Operating procedures and beam alignment procedures shall be documented by the manufacturer and followed by the users. Alignment procedures should be designed so that hands and eyes receive less than a specified amount of radiation exposure. The open-beam units are typically more hazardous than the enclosed beam systems. The open-beam systems are required to have shutters with fail-safe design, and shutters on all ports interlocked with the collimator coupling. A guard or interlock should be used to prevent entry of body parts to the primary beam. The enclosed systems are required to have a chamber interlocked with the high voltage generator so that no x-rays are produced with the chamber open.

Most injuries occur during nonroutine repair and alignment. The users should operate the equipment according to the manufacturer's specifications, and follow the manufacturer's recommended alignment procedures. If modifications are necessary, the radiation protection organization must approve the changes. Also, nonstandard accessories should not be aligned until procedures have been approved. All users and maintenance personnel should be cautioned to not remove covers, shielding materials, tube housings, make modifications to shutters, collimators, or beam stops until the beam is off.

The purpose of ANSI N 43.3-1993, *General Safety Standard for Installations Using Non-Medical X-Ray and Sealed Gamma Ray Sources Energies Up to 10 MeV*, is to keep radiation exposures As Low As Reasonably Achievable (ALARA) due to the wide variety of x-ray and sealed gamma ray sources that are used extensively in industry for the inspection, testing, and analysis of materials.

The Standard classifies installations into five types: shielded installations, exempt shielded installations, certified cabinet x-ray systems, unattended installations, and open installations. The requirements in the Standard are specific to the type of installation, since some installations are inherently less hazardous due to their design. The two types of installations where radiation exposures are most likely to occur are open installations (e.g., mobile x-ray radiography and/or gamma ray radiography that takes place in open areas) or shielded installations (e.g., large, fixed x-ray, or gamma ray machines in a shielded room). The Standard contains requirements for interlocks, audible and visual signals of radiation while it is being emitted, posting of warning signs, and permissible exposure levels. Safety devices, i.e., shutters, lights, and interlocks, are required to be of fail-safe design, which means that if a safety device, like an interlock, fails, exposure is prevented. The safety devices such as shutters, lights, and interlocks are to be tested at least every six months. Many accidental exposures have occurred over the years because workers, attempting to increase production and throughput, intentionally bypass the interlocks by taping down the microswitches.

The Standard also addresses shielding design surrounding these types of sources. Included are recommendations for maintaining shielding effectiveness when conduits, doors, or windows penetrate shielded walls. The appendices contain useful data for calculating shielding thicknesses for gamma ray sources as well as x-ray sources.

10 CFR 34, *Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations*, applies only to sealed gamma ray sources used in radiography by the Nuclear Regulatory Commission (NRC) or NRC Agreement State licensees. It is not a mandatory standard for adoption by DOE facilities. Some of the requirements in this NRC regulation are for exposure devices, such as coupling the source to the drive cable, labeling the source capsule and exposure device, locking the exposure device when not in use, and physically securing the exposure device during transport or storage. Other requirements include leak-testing the source every six months, performing radiation surveys at various stages of radiography, calibrating survey instruments every three months, performing a quarterly inventory of sources, and adhering to requirements for operating and emergency procedures. In 10 CFR 34, three types of personnel monitoring are required: a whole-body film badge or thermoluminescent dosimeter (TLD), a pocket ionization chamber, and an alarming ratemeter. The most frequent cause of accidental exposures (at least among NRC or Agreement State licensees) is a failure of the radiographer to perform surveys, which has resulted in exposures from sources that were left in the unshielded position.

10 CFR 34.31, Training, is the section that addresses the training of radiographers. It is fairly specific in content and time requirements.

DOE/EH-0256T (Revision 1), *Radiological Control Manual*, offers detailed guidance for implementation of radiation protection in the DOE system. It establishes practices for the conduct of DOE radiological control activities, and states DOE's position and view on the best course of action currently available in the area of radiological controls, and states that the site-specific radiological control manual should incorporate ANSI N 43.2 and N 43.3. It also states that management and the radiological control organization should establish control requirements for incidental devices like electron beam welders and electron microscopes, which are not addressed by any of the above standards. The Manual states that DOE facilities should follow the requirements in 10 CFR 34. It mentions that off-site subcontractors performing radiography work on-site must have a valid NRC or Agreement State license. Regarding training, the Manual states that radiographers and operators of RDGs should have training according to the requirements found in 10 CFR 34.31.

NOTE: Statements made in the DOE *Radiological Control Manual* are now considered recommendations, not mandatory requirements, unless the contractor has committed to specific items in their contractual agreement with DOE. The DOE *Radiological Control Manual* is intended to be reissued in 1996 as a RadCon Technical Standard. The use of "shall" statements presently in the document will presumably be changed to "should" (or equivalent) statements.

3. Self-Study Scenarios/Activities and Solutions

Review

- ANSI N 43.2-1988, *Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment*.
- ANSI N 43.3-1993, *General Safety Standard for Installations Using Non-Medical X-Ray and Sealed Gamma Ray Sources Energies Up to 10 MeV*.
- 10 CFR 34, *Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations.*

Scenario

A repairman and an operator were recently exposed to x-rays from an analytical device used in the spectrographic analysis of metal at a DOE facility. The device was an enclosed beam x-ray system. In order to facilitate a repair on the filter holder, a lead beam stop that was part of a multiple sample holder device had been removed. This beam stop is mechanically difficult to remove and is therefore not interlocked. As the repairman was making a telephone call from across the room, the operator entered the room and turned on the x-ray unit. The repairman then returned to work on the filter holder. Over the course of the next 3 to 10 seconds, the repairman inadvertently touched the cooling jacket of the x-ray tube and felt a warm sensation. He immediately realized that the x-ray tube was on and terminated the exposure. During this time, the operator was located approximately one meter from the port. The operator immediately reported this occurrence as a radiation incident to his supervisor.

Describe the hazards to the repairman and the operator. List some follow-up actions to this incident that should be taken by the supervisor and contractor management. Briefly identify the applicable standard(s) and evaluate the incident in relation to requirements of the standard(s).

Your Solution:

Scenario Solution
(Any reasonable paraphrase of the following is acceptable.)

Hazards to the repairman involve exposure to the fingers and hands. Because he was very close to the beam while it was on, it is very likely that his fingers or hands could have actually been in the beam for a short time. The repairman may suffer some acute effects of radiation exposure to his fingers and hands, as well as be at risk for cancer in the area exposed. The operator was standing about one meter away from the beam. He may or may not have received an exposure, depending on the configuration of the system. If exposed, it is likely that only a portion of his body was exposed, since the leakage or scatter beams (the main sources of exposure) would be fairly small in diameter. The operator is probably not going to suffer any acute effects, and his risk of long-term effects will depend on the level of exposure.

Some of the follow-up actions that should be taken by the supervisor and contractor management include:

- Immediately process any personnel monitoring devices that the workers were wearing. The dosimetry processor should be notified of the energy range of the x-rays that may have caused the exposure.
- Interview both workers to determine exactly what happened, in what sequence, and when. The workers should be asked to retrace their movements to the best of their knowledge. It is important that this action be performed as soon as possible after the incident so that the workers' memories are still fresh. It is helpful for two interviewers to document the workers' stories so that discrepancies can be resolved before a final report is written.
- Enact a time-motion study of the workers' actions. Once this has been accomplished, management should obtain radiation exposure measurements to assess worker dose. The measurements should be made with an instrument capable of measuring high exposure rates of low-energy x-rays. Corrections may also need to be made to the instrument reading if the detector chamber is large relative to the size of the beam.
- Refer the workers for medical follow-up. Dosimeter results or radiation measurements may be helpful to the examining physician.
- Evaluate the incident from a management perspective relative to regulatory requirements, notifications, root cause, ALARA, and prevention of future similar incidents.

The most pertinent standard is ANSI N43.2, *Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment.* Probably the most significant deviation from requirements of the standard involves a procedural requirement to ascertain that the tube is off before performing maintenance or modifications. Section 6.5.1 of the standard states, "No operation involving removal of covers, shielding materials, or tube housings; or modifications to shutters, collimators, or beam stops shall be performed without ascertaining that the tube is off and will remain off until safe conditions have been restored. The main switch, rather than safety interlocks, shall be used for routine shutdown in preparation for repairs." Both the repairman and the operator failed to pull the main power switch before repairs.

Section 5.2.2.1.4 requires a visual indicator (light) at the switch as well as at the tube housing. There may have been a visual indicator, but if so, it is unclear why the repairman would not have seen it before resuming repair work. Instead, he realized the beam was on by accidentally touching the cooling jacket of the tube. A visual indicator at the tube housing may have prevented his fingers and hands from receiving an unnecessary exposure.

Once dosimeter results are available, a dose assessment can be performed on the workers. The dose assessment should be based on both the dosimeter results and the incident reconstruction data. Dose assessments will indicate if dose limits were exceeded.

4. Suggested Additional Readings and/or Courses

Readings

- DOE/EH-0256T (Revision 1), *Radiological Control Manual*.
- DOE Order 5480.4, *Environmental Protection, Safety and Health Protection Standards.*
- G-10 CFR 835/C3 (Revision 1), *Radiation-Generating Devices*.
- Lubenau, Joel O., et al. (1969). *Analytical X-ray Hazards: A Continuing Problem*. Health Physics, Vol. 16, pp. 739-746.
- Weigenburg, Irving J., et al. (1980). *Injury Due to Accidental Exposure to X-rays from an X-ray Fluorescence Spectrometer*. Health Physics, Vol. 39, pp. 237-241.

Courses

NOTE: See Appendix B for additional course information

- *Applied Health Physics* -- Oak Ridge Institute for Science and Education
- *Radiation Protection Functional Area Qualification Standard Training* -- GTS Duratek

NOTES: